

Ocean Carbon and Climate Change & North American Carbon Program

Two Science Implementation Strategies prepared for the
Carbon Cycle Science Steering Group and *Interagency
Working Group*

Scott Doney, WHOI

Topics:

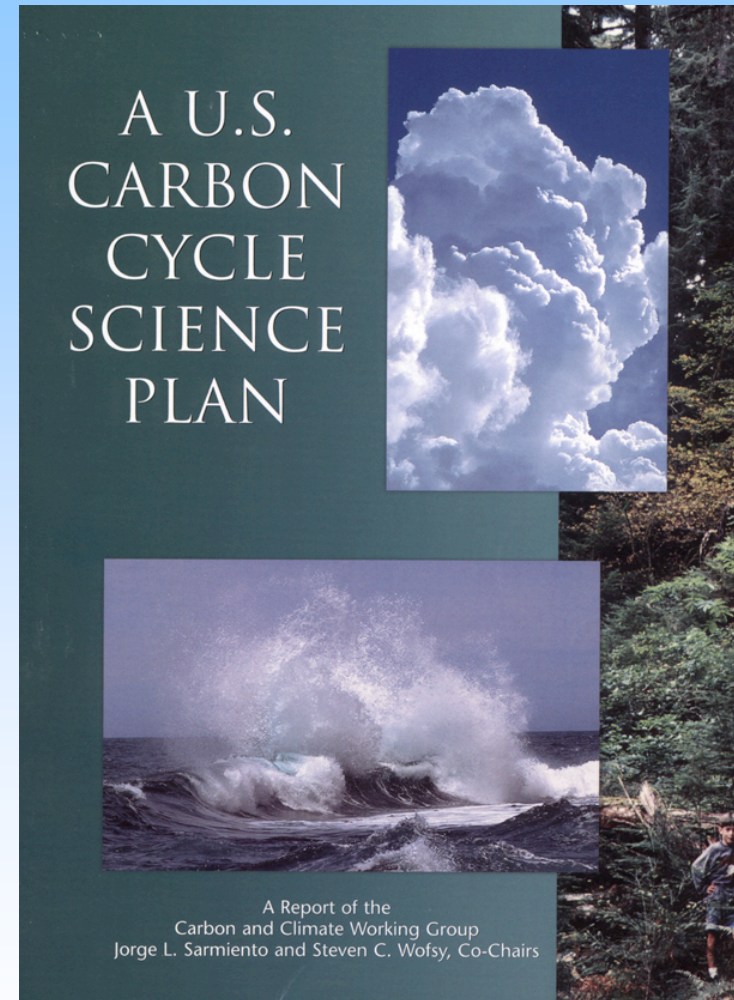
1. Overall scope of the *Ocean Carbon and Climate Change (OCCC)* and the *North American Carbon Program (NACP)*
2. How oceans fit into a NACP and the relationship between NACP and OCCC
3. Highlight roles of NASA and remote sensing
4. Outline the next steps
5. Questions

- ❖ What has happened to the carbon dioxide that has already been emitted by human activities?
- ❖ What will be the future atmospheric CO_2 concentration trajectory resulting from both past and future emissions?

Ocean relevant CCSP Goals:

- Goal 1: Quantify and understand Northern Hemisphere land sink
- Goal 2: Quantify and understand ocean carbon sink
- Goal 4: Improving projections of future atmospheric CO_2

A U.S. Carbon Cycle Science Plan Sarmiento and Wofsy (1999)



The CCSP is Multidisciplinary in
Nature and Global in Scope

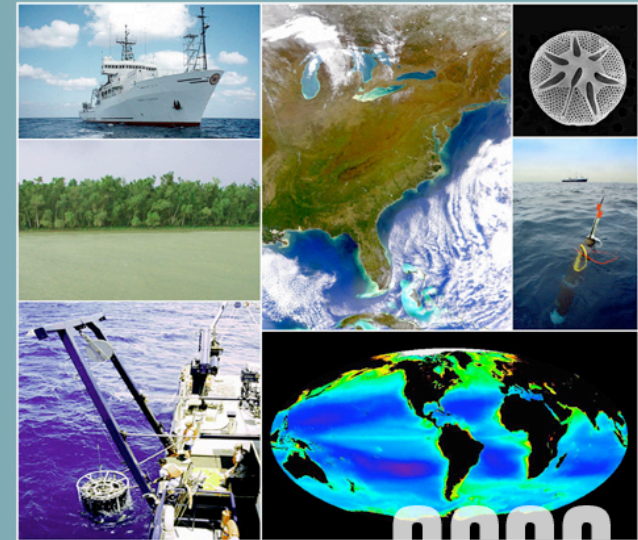
OCCC Overarching Science Vision

Role of the ocean on regulating atmospheric CO₂ levels:

- 1) Ocean natural and anthropogenic CO₂ inventory
- 2) Magnitude and variability of air-sea CO₂ flux
- 3) Feedback mechanisms and climate sensitivities for ocean carbon storage
- 4) Scientific basis for mitigation strategies

Ocean Carbon Observing System
Process and Mechanistic Studies
Southern Ocean Pilot Studies
Synthesis and Numerical Modeling
Methods and Technology Development
Data Management etc.

Ocean Carbon and Climate Change An Implementation Strategy for U.S. Ocean Carbon Research



Prepared for the
U.S. Carbon Cycle Science Scientific Steering Group
and Inter-agency Working Group
by the
Carbon Cycle Science Ocean Interim Implementation Group

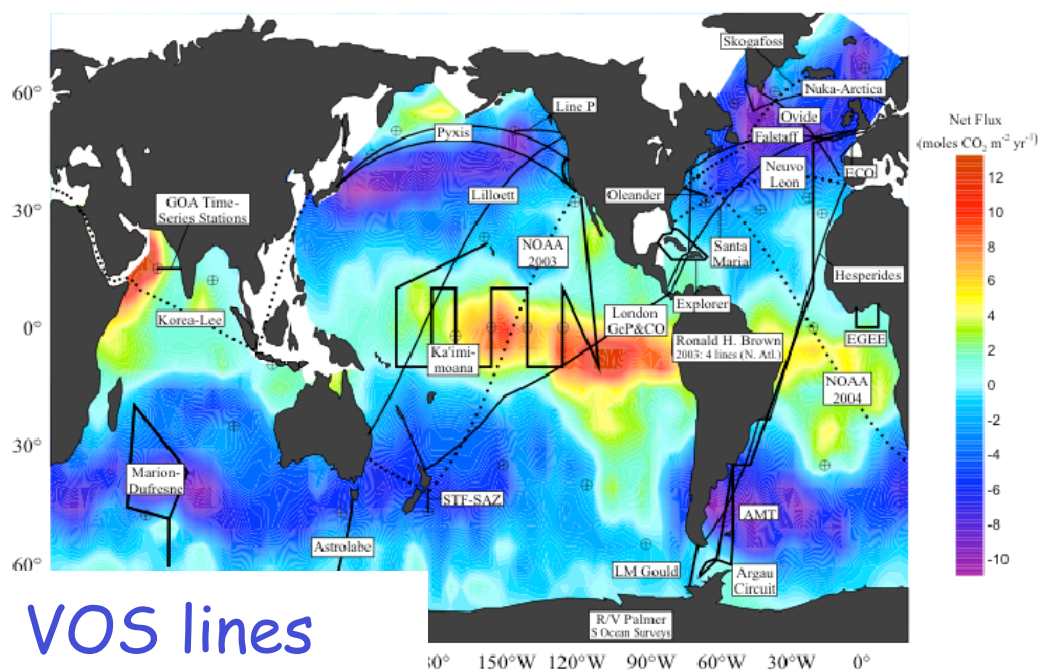
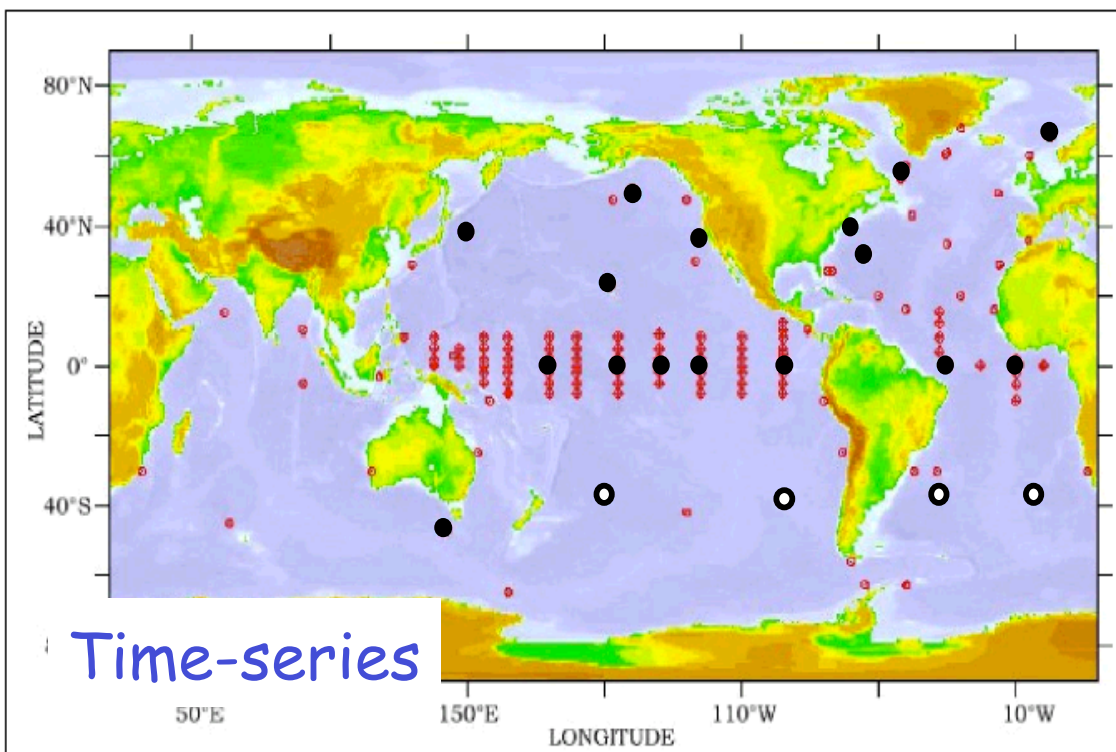
Scott C. Doney
chair and editor

Phased basin-by-basin approach:

Existing/ongoing elements (2003-2005)

Phase 1: N. Atlantic and N. and Eq. Pacific (2005-2011)

Phase 2: Southern Ocean (2011-)



OCCC Phase 1:

- tech. dev., synthesis & modeling and enabling activities (2005=>)
- mid-size process studies at existing TS sites (2005 =>)
- new time-series stations & NA observing network (2006 =>)
- large Northern Hemisphere process study (2008 =>)

OCCC & Remote Sensing

Observing System Elements

Support of time-series, process studies & North American coastal observing network

Algorithm development, validation and analysis of ocean color and related remotely sensed bio-optical properties

Expand in-situ network of sensor calibration sites

Community-wide technical enabling activities

Remote-sensing techniques for quantifying air-sea CO_2 flux

Methods/Technology Development

Operational satellites

Advanced airborne/space systems

New/improved algorithms for atmospheric correction, wider suite of bio-optical properties, and coastal waters

Measurement protocols and in-situ instruments

Synthesis and Modeling

NACP Overarching Science Vision

measuring and understanding the sources and sinks of CO_2 , CH_4 , and CO in North America and adjacent ocean regions and how are they changing over time

1. Diagnostic Analysis:

- remote sensing imagery;
- atmospheric observing system;
- hydrologic transfers (land=> coastal ocean);
- open and coastal ocean measurements;
- modeling (process-based => data assimilation);
- interdisciplinary intensive field campaigns

001, Carbon exchange over southeast biome of US

002, Coastal ocean field intensive site

003, Mid-continent intensive NACP campaign

004, Enhanced forest land measurements

005, West coast intensive experiment

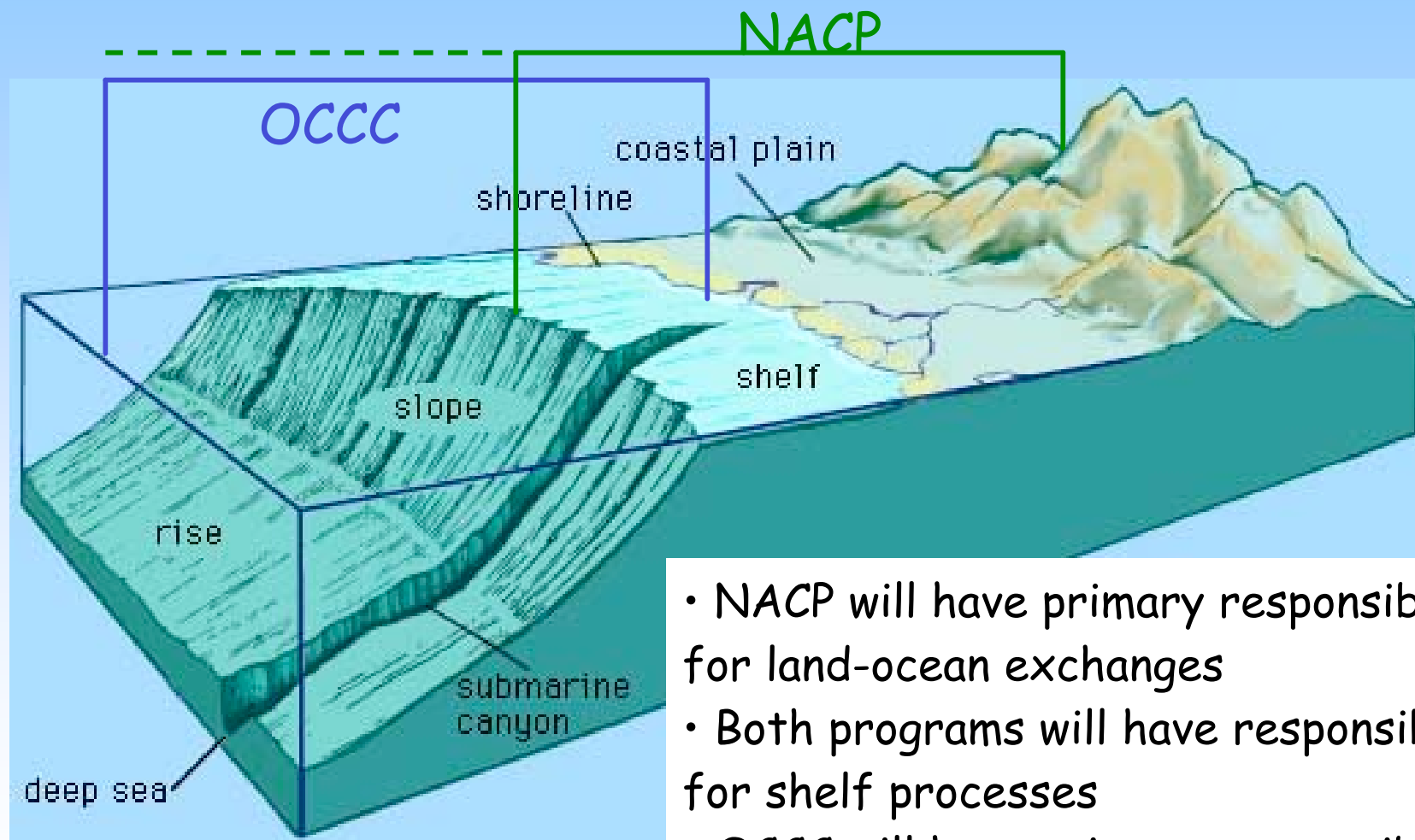
006, Surface and atmosphere carbon cycle gas exchange -- southern great plains

2. Process-Oriented Research:

3. Predictive modeling:

4. Decision support resources:

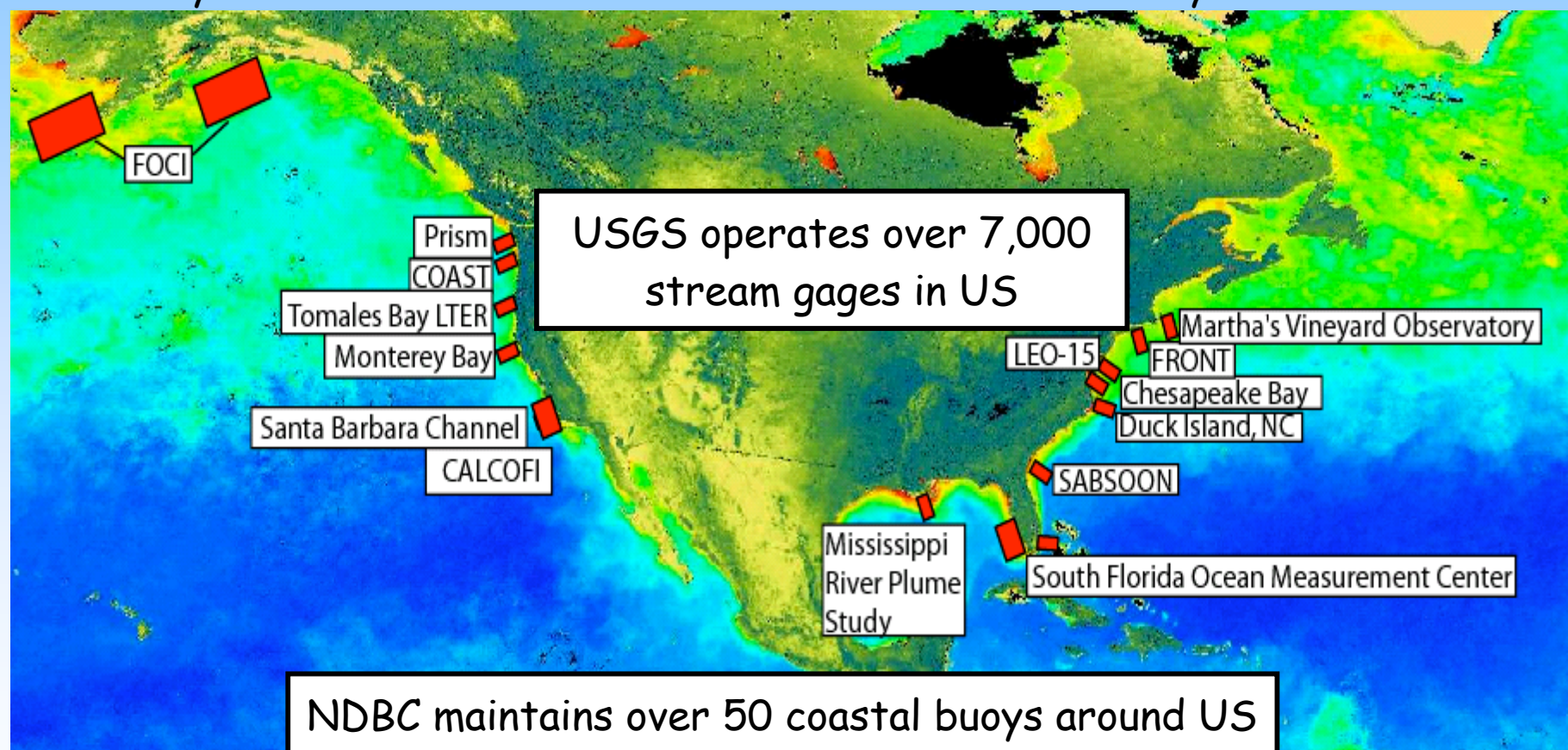
The approach we have taken is to coordinate both NACP and OCCC to give us a continuum from dry land to the open ocean



- NACP will have primary responsibility for land-ocean exchanges
- Both programs will have responsibility for shelf processes
- OCCC will have primary responsibility for shelf-open ocean exchanges

To make a coastal observing system a reality we must build on existing infrastructure

Most study areas will need to be enhanced to include carbon system measurements



The primary need for NACP is to place the numerous small-scale individual studies into a continental-scale context (i.e. NACP needs to tie it all together and fill in the gaps)

Ocean Carbon and Climate Change
An Implementation Strategy for U.S. Ocean Carbon Research



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- OCCC Report released
- NACP Report in final draft
- Discussions ongoing about forming SSCs and Project Offices
- Joint NACP/OCCC Coastal Observation Workshop in late 2004

Hard copies of the OCCC report are available:

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U.S. Climate Change Science Program
1717 Pennsylvania Avenue, NW Suite 250
Washington, DC 20006 U.S.A.



A pdf version can be downloaded from: <http://www.carboncyclescience.gov>



OCCC Overarching Science Vision

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Phased basin-by-basin approach:

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(2005-2011)

Phase 2: Southern Ocean (2011-)

Ocean Carbon and Climate Change An Implementation Strategy for U.S. Ocean Carbon Research



OCCC

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Geophysical Quantity	Remote Sensing Platform	Status*	Coverage
Chlorophyll-a	SeaWiFS, MODIS, MERIS, GLI, POLDER, VIIRS) (Ocean color satellite sensors)	Operational ¹	Global*
Primary Production	Ocean color satellites	Operational	Global
Photosynthetic Efficiency	MODIS (passive fluorescence) Aircraft (lidar & passive fluorescence)	Developmental ² Developmental	Global Local [#]
CDOM	Ocean color satellite sensors	Developmental	Global (Regional ¹)
DOC	Ocean color satellite sensors	Conceptual ³	Global (Regional)
POC	Ocean color satellite sensors	Developmental	Global (Regional)
Calcite	Ocean color satellite sensors	Operational	Global
Bicarbonate	Shipboard laser	Conceptual	Local
SST	AVHRR, MODIS, MERIS, GLI, VIIRS)	Operational	Global
Surface Wind Speed	SSM/I (passive microwave) QuikScat, SeaWinds (scatterometry)	Operational	Open Ocean
Sea Level	TOPEX, JASON	Operational	Open Ocean
SSS	Aircraft (passive microwave) Aquarius (passive microwave)	Operational Developmental	Local Open Ocean

Ocean carbon cycle remote sensing observations

Major NACP *diagnostic studies* planned for 2005-2006

1. Systematic compilation and analysis of new and existing remotely sensed imagery for use in models of carbon exchange at both land and ocean surfaces;
2. An atmospheric observing system consisting of ground stations, aircraft and measurements from towers, ships and buoys;
3. Estimates of hydrologic transfers of carbon over land, transformations in estuaries, and sequestration in sediments on land and in coastal oceans;
4. Ocean measurements and modeling, both in the coastal zone and the open ocean, in coordination with OCCC (Doney et al., 2004);
5. Synthesis and integration activities organized into three interlocking strategies: process-based models driven by many kinds of observations; top-down synthesis; and model-data fusion and data assimilation;
6. Interdisciplinary intensive field campaigns designed to evaluate major components of the model-data fusion framework.

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Joint NACP/OCCC Coastal Observation Workshop in 2004

The goal of this workshop will be to pull the coastal oceanography community together to discuss what is currently being done on the North American coasts and to discuss scaling issues for implementing a continental-scale observing program (science meeting with program relevance).

A small scientific steering group would then interface with the program managers to develop a plan and timeline for implementing the strategies outlined in the NACP and OCCC documents.

Ideally a program office would be established to coordinate the projects and host regular meetings of the PIs in a manner similar to the annual JGOFS SMP PI meetings. These meetings will inform the community about which approaches work or do not work, encourage collaboration and communication between groups, identify gaps or new directions necessary for the next program call for proposals.



The oceans have been a part of
NACP from the beginning

First NACP Workshop, Boulder, CO
Sept. 5-7, 2001



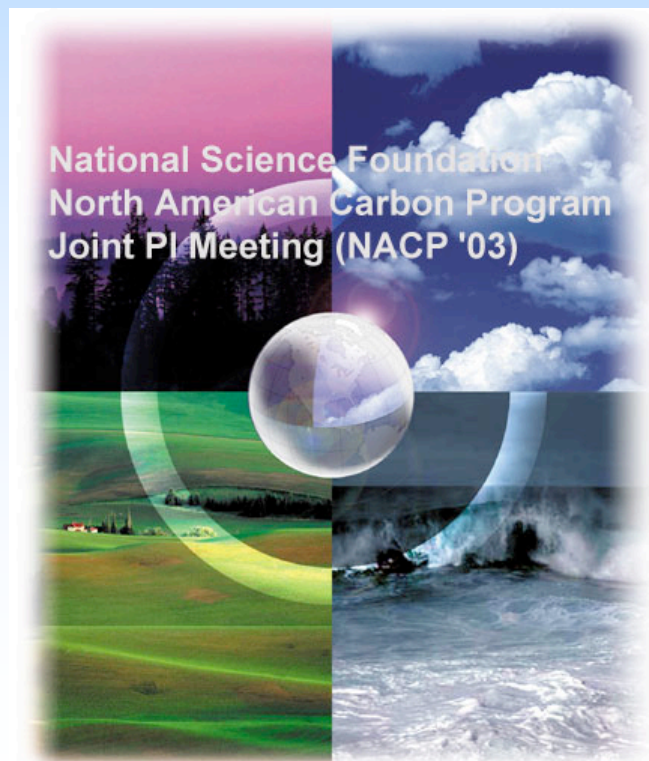
Science Plan published in 2002



Second NACP Workshop, Arlington, VA
May 12-14, 2003



Science Implementation Strategy for the
North American Carbon Program



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OCCC Implementation Elements (Phase 1)

Ocean Carbon Observing System

- Repeat hydrographic survey
- Volunteer-Observing-Ship (VOS) pCO₂ surveys
- Time-series measurements
- North American coastal observing network
- Remote sensing

Process and Mechanistic Studies

- Upper water column & mesopelagic processes
- Continental margin biogeochemistry
- Air-sea gas exchange

Southern Ocean Pilot Studies

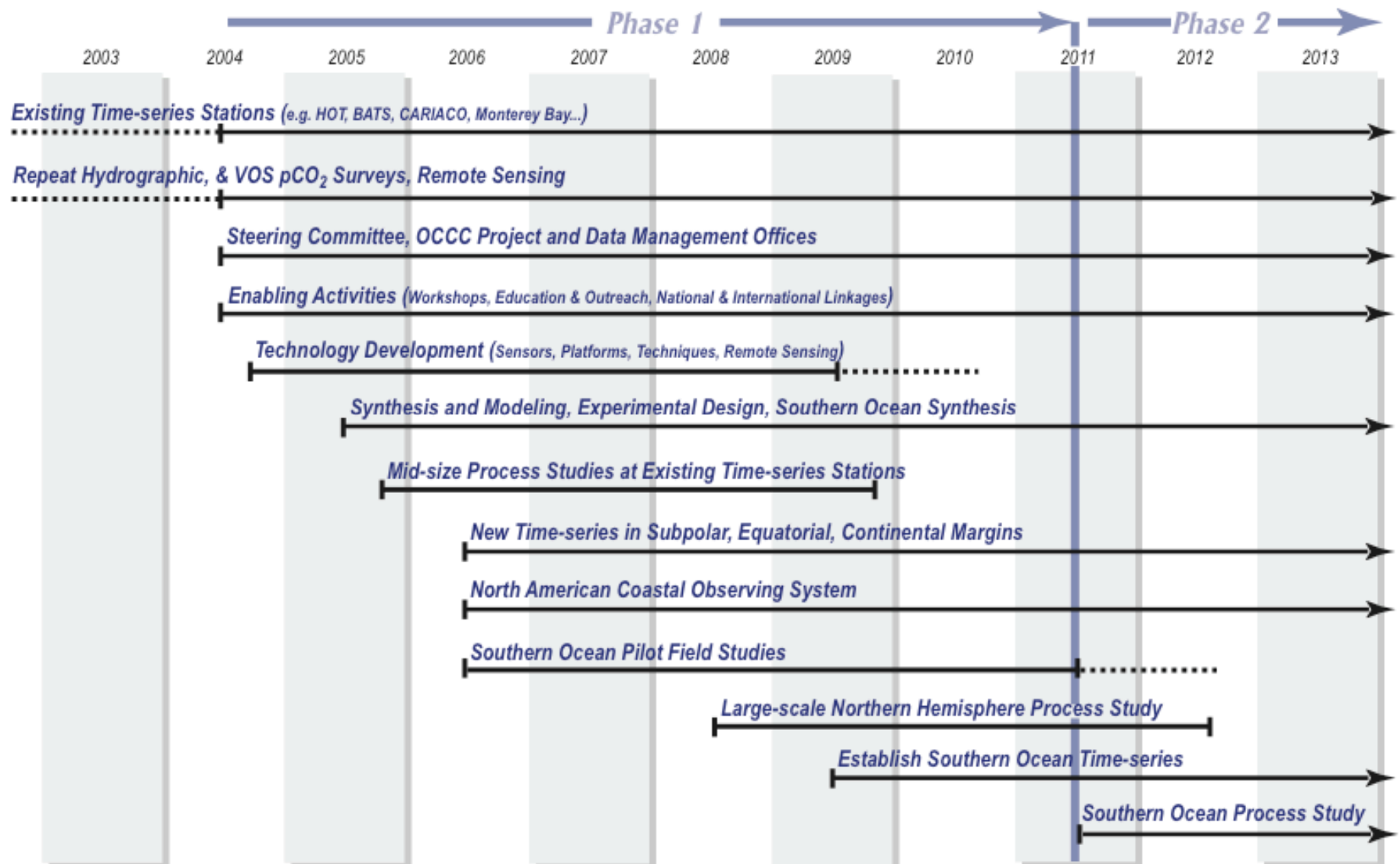
Synthesis and Numerical Modeling

Methods and Technology Development

- Chemical & biological techniques
- Sensors, platforms & remote sensing

Enabling Activities

Timeline of OCCC Implementation Strategy



How do we define North America?

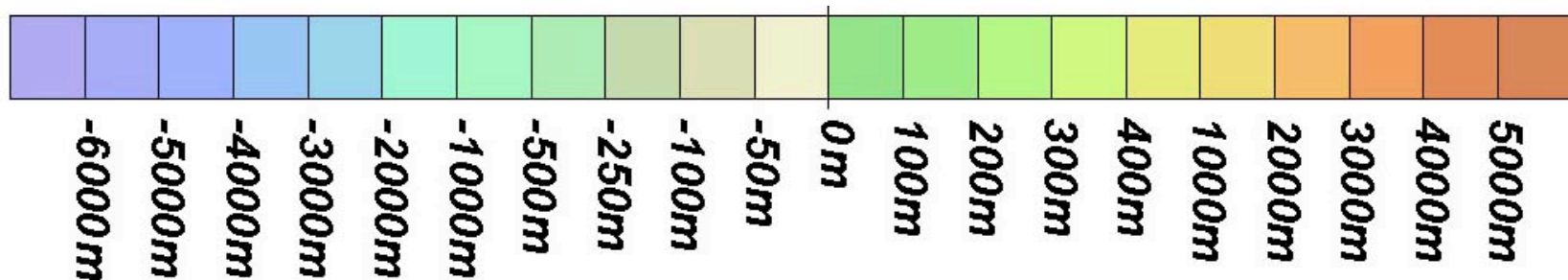
Is it just
dry land?

Or is it out
to the EEZ?

Or is it between
Hawaii and
Bermuda,
background
stations for
determining NA
sink?

Or is it 1000 km
offshore to
encompass the
footprint of the
coastal tall
towers?

Or is it to the edge of the continental shelf?



Major *diagnostic studies* are planned for 2005-2006

1. A hierarchical network of large-scale, distributed terrestrial measurements;
2. Systematic compilation and analysis of new and existing remotely sensed imagery for use in models of carbon exchange at both land and ocean surfaces;
3. Substantially improved fossil fuel emissions inventories with high resolution in time and space, and methods for evaluating these inventories using atmospheric measurements;
4. An atmospheric observing system consisting of ground stations, aircraft and measurements from towers, ships and buoys;
5. Estimates of hydrologic transfers of carbon over land, transformations in estuaries, and sequestration in sediments on land and in coastal oceans;
6. Ocean measurements and modeling, both in the coastal zone and the open ocean, in coordination with the ocean carbon component of the Carbon Cycle Science Program (OCCC; Doney et al., 2004);
7. Synthesis and integration activities organized into three interlocking strategies: process-based models driven by many kinds of observations; top-down synthesis; and model-data fusion and data assimilation;
8. Interdisciplinary intensive field campaigns designed to evaluate major components of the model-data fusion framework.

process-oriented research activities under NACP

1. Responses of terrestrial and marine ecosystems to changes in atmospheric CO₂, tropospheric ozone, nitrogen deposition, and climate;
2. Responses of terrestrial ecosystems to changes in disturbance regimes, forest management, and land use;
3. Responses of terrestrial ecosystems to agricultural and range management;
4. The impacts of lateral flows of carbon in surface water from land to fresh water and to coastal ocean environments;
5. Responses of coastal marine ecosystems and sedimentation to eutrophication and other disturbances from human activity; and
6. Human institutions and economics;

predictive modeling activities supported under NACP

1. Transfer of synthesized information from process studies into prognostic carbon-cycle models;
2. Retrospective analyses to evaluate the spatial and temporal dynamics of disturbance regimes simulated by prognostic models;
3. Evaluation of predictions of interannual variations with predictive models against continued monitoring using legacy observational networks and diagnostic model-data fusion systems;
4. Development of scenarios of future changes in driving variables of prognostic models;
5. Application and comparison of prognostic models to evaluate the sensitivity of carbon storage into the future; and
6. Incorporation of prognostic models into coupled models of the climate system.

decision support resources to be provided by NACP

1. Economics and energy policy options for management of the carbon cycle given improved understanding, diagnosis, and prediction;
2. Longevity of sinks;
3. Scenario development for simulation of future climate;
4. Assessment of sequestration options given best scientific evaluation of present and future behavior of carbon cycling.

Carbon Cycle Science Questions

1. What are the magnitudes and distributions of North American carbon sources and sinks and what are the processes controlling their dynamics?
2. What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time-scales, and which processes control their dynamics?
3. What are the magnitudes and distributions of global terrestrial, oceanic, and atmospheric carbon sources and sinks and how are they changing over time?
4. What are the effects of past, present, and future land use change and resource management practices on carbon sources and sinks?
5. What will be the future atmospheric CO_2 and CH_4 concentrations, and how will terrestrial and marine carbon sources and sinks change in the future?
6. How will the Earth system, and its different components, respond to various options being considered by society for managing carbon in the environment, and what scientific information is needed for evaluating these options?

Elements of the OCCC implementation strategy

- Enhancing the global ocean carbon observing network based on global carbon hydrographic surveys, surface water observations, time-series, satellite remote sensing, and a North American coastal observing system.
- Conducting targeted, multi-disciplinary process studies on the response of upper ecosystems and air-sea CO_2 flux to inter-annual climate variability, biogeochemical cycling in the mesopelagic zone, continental margin carbon dynamics, and air-sea gas exchange.
- Integrating field observations, remote sensing, data synthesis and numerical modeling through forward prognostic models as well as inverse and data assimilation techniques.
- Accelerating enabling activities such as technology development, data management and accessibility, cross-disciplinary and international cooperation, workshops, education and outreach, contributions to national carbon assessments, and ongoing scientific oversight and coordination.

